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(19)

(72) Inventors ERIC CHARLES HOPSON
WILLIAM GEORGE ROWLAND

(54) SHREDDING MACHINES

(71) We, METAL BOX LIMITED of Queens House, Forbury Road, Reading RG1 3JH (formerly THE METAL BOX COMPANY LIMITED of 37 Baker Street, London W1A 1AN), a British company, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to shredding machines of the kind having a machine housing and a plurality of inter-engaging rotatable cutter assemblies in the housing, each cutter assembly being arranged to rotate about its own axis in the opposite direction from the or each said assembly engaging therewith to comminute material fed into the housing, said axes being parallel, each cutter assembly including at least one generally disc-like cutter element, each of which has an end face bounded by a peripheral cutting edge in a plane perpendicular to the axis and axially opposed to a closely adjacent similar end face of a co-operating cutter element of another said assembly having a plurality of said elements, so that in two co-operating cutter assemblies, every cutter element (except two end most ones) lies in an intermediate axial position between two cutter elements of the other of the two assemblies, each said end face being bounded by a peripheral cutting edge defining at least one radial tooth of the cutter element and at least one radial recess peripherally displaced therefrom, and each cutting edge having a shape such that, throughout rotation, there is an overlap between cooperating end faces to define an interface between the respective cutting elements perpendicular to the axes of rotation.

Such a machine will be referred to herein as a shredding machine of the kind hereinbefore specified. The invention is also concerned with a cutter assembly for a said shredding machine of such a kind, and with cutter members comprising a said cutter element for inclusion in a cutter assembly for a shredding machine of such a kind.

Shredding machines of the kind hereinbefore specified are known in various forms, mainly for the commination of waste matter. Typically, in such known machines the cutter assemblies each comprise a shaft carrying a plurality of cutter members arranged along the shaft coaxially therewith. Each cutter member consists of or includes a radially-extending disc-like element having a periphery so profiled that, upon rotation of the cutter assembly and of the other cutter assembly with which it is associated, the disc-like element acts, in the region of its periphery, upon the material to be comminuted. Considered axially with respect to the cutter assembly shafts, the disc-like elements of one cutter assembly are spaced apart to define a gap between each such element and the next one on the same shaft, the disc-like elements of the other cutter assembly extending radially into these gaps so that the disc-like elements of the two assemblies are in radially-overlapping and alternate relationship. Material to be comminuted is fed on to the cutter assemblies in the region of this overlap and in the direction in which the profiled peripheries of the disc-like elements are moving in this region when rotating in opposite directions. Typically this direction is downwards, the two shafts being parallel with each other and their axes of rotation being in a common horizontal plane.

The material to be comminuted is most usually scrap or waste material. The machine may be adapted for shredding particular kinds of objects and/or materials, for example old rubber tyres or metal cans; equally it may be made suitable for shredding heterogeneous rubbish which may—and probably will—include items of widely

varying size, shape, texture, resilience, and mechanical resistance to cutting, tearing, distortion or crushing. The present invention is applicable to the comminution both of such heterogeneous material and of matter more invarying in its properties. In either case the material to be comminuted may be waste matter, or it may for example be material which requires to be shredded as part of some industrial process.

Although some known machines are commonly referred to as shredding machines, their comminuting action takes a form or forms which depend largely on the nature of the material being comminuted and on the design of the cutter members. For example, the action of the so-called cutter members typically includes very little actual cutting. Glass, for instance, will tend to be crushed into small pieces; and other common materials such as thin metal, will tend to be torn and/or deformed by crushing.

In order to obtain as reliably as possible the maximum practicable reduction in volume, it is desirable that the material to be comminuted shall be reduced to pieces as small as may be consistent with satisfactory subsequent ability to be handled. In this way also a measure of consistency is obtained in the comminuted material, and this is especially desirable in the case of heterogeneous rubbish. To this end the greatest possible cutting efficiency is desirable, as is the predominance of cutting over other methods of reducing the material to pieces, such as crushing or tearing.

In one known machine of the kind hereinbefore specified, the cutter assemblies rotate at different speeds, each cutter assembly having a plurality of cutter members each comprising a circular disc with one tooth projecting radially therefrom. Each tooth is in the form of a forward-facing hook, the effect of which is to pierce the material to be comminuted and force it down between the two rotating cutter assemblies. This type of machine is found to have a disadvantage in that material often tends to be urged upwardly away from the co-acting region of the cutter assemblies, so that the piercing action and ability of the cutter teeth to force the material into this co-acting region is necessary in order to obtain reasonable efficiency. The circumferential distance between the leading edge of a tooth and the back of another is limited by the size of items to be comminuted: and whilst it is possible to provide more than one tooth per cutter, the basic disadvantages remain. Another important disadvantage of this known type of machine is that such cutting as does occur—most of the comminuting action is in fact crushing or tearing—is found to take place only over that part of the cutter disc periphery that coincides with the projecting tooth. For the greatest possible cutting efficiency it is desirable that cutting shall take place over most or all of the periphery of each cutter member. This also reduces the need for reliance on tearing or crushing, which require somewhat greater power than does pure cutting.

Another known machine has two cutter assemblies contra-rotating at the same speed, each assembly consisting of a number of cutter members, each having a single peripheral cutting edge defining an end face of the member; the back of the member, which abuts the end face of the next cutter member, has a smaller diameter than this end face. The cutting edges are profiled with the intention of obtaining a continuous cutting action, to which end the co-operating end faces of each pair of cutter members (one member of each pair being in one assembly and one in the other assembly) are arranged to have a very small overlap. In practice it is found that with this type of machine effective cutting takes place only over that part of the periphery of each cutter member defined by three projecting lobes of the cutter member, and thus only during a proportion of each revolution. This proportion is found to be about fifty per cent.

According to the invention, in a shredding machine of the kind hereinbefore specified each cutter element lying between two cutter elements of a co-operating cutter assembly has two said cutting edges, each of which is substantially continuous and bounds substantially all of a respective one of the two opposed end faces of the element in face-to-face engagement with the co-operating cutter element, so that the number of said perpendicular interfaces is one less than the total number of cutter elements in two co-operating cutter assemblies.

This arrangement according to the invention provides cutter elements in face-to-face cutting engagement, i.e. virtually in sliding contact, with two similar elements of the other cutter assembly. This tends to balance out or equalise the end thrusts which are imposed on the cutter elements by asymmetrical loads applied by the material being cut. Another important advantage is that it nearly doubles the number of active cutting points for a given number of cutter elements.

Preferably two cutter assemblies are provided, one of which has one cutter element more than the other cutter assembly. This arrangement further helps to balance out the end thrusts.

According to a preferred feature of the invention, the shape of each of at least one pair of co-operating cutting edges is such that, over at least a major portion of each revolution, the included angle (as defined

below) between them is such as to cause a positive cutting action to occur between the corresponding cutter elements.

The said included angle is the angle, at any point on the periphery of a first of two co-operating cutter elements, between the tangent to the periphery at that point and the tangent to the periphery of the second of said cutter elements at a point which, during contra-rotation of the cutter assemblies, meets the said point on the first cutter element whereby the two said points instantaneously define the rearward extremity of overlapping portions of the two respective cutter elements.

We have found that cutting action depends on the value of this included angle, which has a maximum value for effective cutting action, this maximum value being dependent wholly or partly on the thickness of the material to be cut. For shredding heterogeneous rubbish of the kind normally discharged from domestic or catering establishments, for example, a predominant component of the rubbish being metal cans, it is found that this maximum value for the included angle is about 30 to 40 degrees. In one preferred form of shredding machine according to said first aspect of the invention, at least 90% of the periphery of each cutter element is so profiled that the included angle is less than 30 degrees.

For shredding vehicle tyres, it is found that a cutter element design giving an included angle of not more than about 40 degrees over substantially more than half of the cutter member periphery produces satisfactory results in a machine according to the invention.

Shredding machines of the kind hereinbefore specified may be designed to operate so that the material to be shredded passes only once through the cutter assemblies. Alternatively they may be so arranged that the material can recirculate, to pass more than once through the cutter assemblies and be comminuted thereby in two or more stages. Among shredding machines proposed hitherto, it is known to permit such recirculation to occur randomly.

According to another preferred feature of the invention, the machine includes fixed recirculation guide means associated with the cutter assemblies, for guiding material along a substantially controlled path from the discharge side of the co-operating cutter assemblies towards the inlet side thereof, the guide means being discontinuous in the direction of the cutter assembly axes so that material of sufficiently small size can escape.

Preferably the arrangement is such that the fixed guide means carry material part of the way towards the inlet side of the cutter assemblies, the latter urging the material back to the inlet side in a random manner so that some of it may tend to be re-orientated before being further comminuted.

The guide means are so arranged that the material when comminuted to pieces of sufficiently small size, is no longer recirculated but is allowed or caused to be discharged without passing along the guide means.

In the preferred embodiment, the guide means include a fixed, substantially arcuate plough-like guide radially spaced from each cutter element and extending part-way around the latter from the discharge side of the cutter assemblies to a point short of the inlet side. Each said guide is so spaced from the associated cutter element radially that partially-comminuted material, after passing through the cutter assemblies, can be urged in a controlled manner along the fixed guide by the projecting teeth of the cutter element. In a shredding machine according to the invention, comminution is achieved mainly by cutting action and the material therefore tends to be cut into strip-like form. Thus the strips of material are urged lengthwise along the guide members to the end of the latter, whence they are carried randomly by the rotating cutter elements back to the inlet side. During this random movement, it is found that some of the strips of material tend to rotate so as to lie across the cutter elements, so that upon entering the cutting region of the cutter assemblies once again, such strips are cut in several places.

Especially, though not exclusively, where the machine is to be used for comminuting bulky objects such as rubber tyres, it is advantageous and may be essential to arrange for these objects to be located accurately and deliberately at the inlet side of the cutter assemblies. Accordingly the machine may include inlet guide means having a fixed guide member between one cutter element and the next in the same cutter assembly, the or each said guide member being directed generally towards a cutting zone in which co-operating end faces of the cutter elements overlap.

There may also be provided a ram or pusher for forcing the tyre or other object past the inlet guide means and into the cutter assemblies. This can impose considerable stresses on the inlet guide means, which however are desirably made as light as possible. To this end, the inlet guide means preferably includes between one cutter element and the next a support member fixed with respect to the associated fixed guide member and arranged so that the support member and guide member straddle and are supported by a spacer element between the opposed end faces of the said one and the next cutter element. The said spacer ele-

ments are preferably provided in any case, between each cutter element and the next in the same assembly, and form part of the cutter assembly. The spacer elements may be integral with the cutter elements or separate therefrom.

Again especially for handling large objects such as tyres, it may be necessary to make each cutter assembly relatively long. Since with a tyre the greatest load is in the region of the middle of the cutter assembly, and since the middle is also furthest from the end bearings in which the assembly will (most typically) rotate, it is desirable in such applications to support each cutter assembly intermediately between its ends, but without interrupting the succession of cutter elements along the assembly.

Accordingly, a preferred feature of the invention provides that, where each cutter assembly is mounted for rotation in end bearings, the machine includes intermediate support means for at least one of the cutter assemblies, the or each intermediate support means being between two adjacent cutter elements and comprising a pair of support members freely rotatable about axes disposed parallel to the corresponding cutter assembly axis but not in a common plane therewith.

The cutter members of each cutter assembly having a plurality of cutter members may be mounted in the assembly in any convenient manner: for example they may be bolted, keyed or splined, or shrunk on to a shaft coaxial with the cutter members, and/or secured to it by bonding with a suitable bonding agent. The cutter members may be provided with end spigots each engaging in a corresponding end recess in the next adjacent cutter member; in such an arrangement the cutter members may be made such that a central shaft is unnecessary, the assembly being self-supporting and sufficiently strong and rigid without a shaft. In most cases it may however be more convenient to provide a shaft on which the cutter members are mounted.

In one embodiment of the machine according to the invention, a plurality of cutter members in a cutter assembly have longitudinally-extending spigot means engaging in wedging relationship within end recesses formed in adjacent cutter members, said recesses and spigot means constituting eccentric elements intersected by but having axes slightly offset radially from the axis of rotation.

Preferably in each cutter member having a said eccentric element at each end, the offset axes of the two eccentric elements are themselves angularly offset from each other. Thus in an assembly comprising three or more cutter members, the offset centres of the various eccentric elements can be arranged to define together a helix concentric with the axis of rotation of the cutter assembly. There will normally be a said spigot means at one end of the cutter member and a said recess at the other. It is however possible to provide alternately a cutter member having a spigot means at each end and a cutter member having a recess at each end.

Where the cutter assembly includes a central shaft, the axis of the shaft is the axis of rotation of the cutter assembly. It is found that with this arrangement, a secure and rigid, and very strong, cutter assembly is obtained by bonding the cutter members to the shaft, and bonding the eccentric elements, if provided, together, by means of a suitable adhesive, typically an industrial resin-type adhesive. The whole assembly is structurally homogeneous, so that end loads applied to one of the cutter members of the assembly tend to be spread substantially evenly over the whole cutter assembly.

One form of shredding machine embodying the invention, and a modification thereof, will now be described, by way of example, with reference to the accompanying drawings in which:—

Figure 1 is a diagrammatic side elevation of the shredding machine;

Figure 2 is a sectional, part cut-away, plan view taken on the line II-II in Figure 1 but to a much larger scale;

Figure 3 is a sectional end elevation taken on the line III-III in Figure 2;

Figure 4 is a diametric sectional part-elevation of part of a said cutter assembly of the machine shown in Figures 1 to 3;

Figure 5 is a diagram showing part of the peripheral profile of a six-lobe cutter member of the same machine;

Figure 6 is a sectional elevation taken on the line VI-VI in Figure 7, showing a said modification;

Figure 7 is a plan view taken on the line VIII-VIII in Figure 6; and

Figure 8 is a diagram showing part of the peripheral profile of a three-lobe cutter of the machine shown in Figures 6 and 7.

Referring to Figure 1, the shredding machine shown therein includes a generally-rectangular machine housing 10 mounted on a frame 11. The housing 10 is open at the top and surmounted by a filling hopper 12. The housing is also open at the bottom, to discharge into a suitable receptacle such as a removable bin 13. Within the housing 10 there is a pair of inter-engaging rotatable cutter assemblies each including a cutter shaft 14. The cutter shafts 14 are mounted in end bearings with their axes horizontal and parallel, and one end of each shaft projects through the housing side wall 15 and carries a gear 16. The gears 16 are identical

to each other and form part of a suitable transmission 17 whereby the cutter shafts 14 are driven at the same speed as each other, but in opposite directions, from a main drive motor 18 of the machine mounted on the frame 11.

Referring now to Figures 2 and 3, the cutter assemblies are indicated respectively by the reference numerals 19 and 20. Each cutter assembly 19, 20 has five cutter members, each of those in the assembly 19 being designated by the reference numeral 21 and each of those in the assembly 20 being designated by the reference numeral 22. The ten cutter members 21, 22 are substantially identical with each other. Each cutter member 21 co-operates with a cutter member 22 of the other assembly and is in overlapping relationship therewith in the cutting zone indicated at 23 in Figure 3.

Each cutter member comprises a substantially disc-like cutter element 24 and an integral longitudinally-projecting spacer bush 25 coaxial with the element 24. Each cutter element 24 has two opposite end faces 27, each in a plane perpendicular to the axis and facing oppositely from the closely adjacent, similar end face 27 of the co-operating cutter element 24 of the other cutter assembly. The above-mentioned overlapping relationship exists between each pair of oppositely-facing, closely adjacent co-operating end faces 27, which are in close engagement with each other to define an interface, perpendicular to the axes of rotation, between the respective co-operating cutting elements in the area of overlap between them. Each end face 27 is bounded over its entire periphery by a peripheral, continuous cutting edge having a shape defining a profile for the corresponding end face 27 such that this overlap between the end faces exists throughout rotation of the cutter assemblies.

The cutter members of each cutter assembly 19, 20 are arranged on the appropriate cutter shaft 14 of the assembly in end-to-end relationship as is seen best in Figure 4, with an end face 26 of the bush 25 of one cutter member abutting one end face 27 of the cutter element 24 of the next cutter member, the cutter members being secured to each other and to the shaft 14 in a manner hereinafter to be described.

The length of each spacer bush 25 is such, in relation to the axial length (i.e. the thickness) of each cutter element 24, that between each element 24 and the next element 24 of the same cutter assembly 19 or 20, there is a gap 28 just sufficient to accommodate the cutter element 24 of a co-operating cutter element 24 of the other assembly and to allow relative rotation between them, such that each of the cutter elements (other than one endmost one of each cutter assembly) is in face-to-face cutting engagement with two cutter elements of the other assembly. The said endmost cutter elements are in face-to-face cutting engagement each with only one cutter member. This face-to-face relationship is defined, for all the cutter members, by the above-mentioned interface in the overlapping area of their radial faces 27 in the cutting zone 23, Figure 3, as indicated at 29 in Figure 2. Thus, for example, a cutter element of a member 21 of cutter assembly 19 is disposed between the cutter elements of two members 22 of cutter assembly 20, the two members 22 being spaced apart longitudinally; each of the latter has one of its cutting edges co-operating with a first cutting edge of the member 21 between them, and defines a respective end face 27 facing towards that end face 27 of the other member 22 which is defined by the cutting edge of the latter co-operating with the other or second cutting edge of the member 21. It will be seen that the number of said perpendicular interfaces is one less than the total number of cutter elements in the two cutter assemblies, i.e. there are ten elements 24 and nine interfaces 29.

The cutting edges at the periphery 30 of the cutter element 24 of each cutter member 21, 22 are so profiled that, over at least a major portion of each revolution when the cutter assemblies 19, 20 are rotated by the motor 18 at the same speed as each other in contra-rotation as indicated by the arrows 31 in Figure 3, the included angle (as hereinbefore defined) A, Figure 3, between any two co-operating cutter members 21 and 22 is small enough to cause a positive cutting action to occur between them.

Referring now to Figure 3 and considering the point 32 on the periphery of the cutter member 21 which, in the relative positions of the cutter members 21, 22 shown in the Figure, meets the point 33 on the periphery of the member 22 during contra-rotation of the cutter assemblies 19, 20, these two points 32 and 33 then define the instantaneous rearward extremity, considered in the direction of rotation 31 of the cutter members, of the overlapping portions of the latter which define the cutting zone 23. The included angle A is then instantaneously the angle between the tangent 34 to the periphery of the cutter member 21 at point 32 and the tangent 35 to the periphery of the member 22 at point 33.

The profile of each cutter member periphery 30 is such in this example that the included angle A, while varying as the cutter members 21, 22 rotate, is, over at least 90 per cent of each revolution less than 30 degrees. One suitable profile of the periphery 30 is shown in Figure 3 for both

cutters 21 and 22, and is illustrated in greater detail, by way of strictly non-limiting example only, in Figure 5. It will be seen that in this example the cutting edge of the cutter element 24 of each cutter member 21 or 22 defines six equally-spaced radial teeth or projections 36 and six radial recesses alternating with and therefore peripherally displaced from the teeth. The profile between the tip 37 of each projection 36 and the tip 37 of the next is identical, so that from Figure 5 the whole profile of the periphery 30 can be deduced. The profile is formed on a base circle 38 having a radius of 100 mm. In Figure 5, each linear dimension is given in millimeters, the letter "*R*" standing for radius.

The profile illustrated in Figure 5 gives an included angle *A*, Figure 3, of less than 30 degrees over about 96% of each revolution, thus enabling material to be cut by positive cutting action of the co-operating cutter members 21, 22 in the cutting zone 23, Figure 3, over at least 96% of each revolution. Again with this profile, the included angle *A*, when the cutter members 21, 22 are in the positions shown in Figure 3, is about 21 degrees.

Referring now to Figures 3 and 4, the cutter members 21 and 22 are provided with longitudinally extended spigots 39 each engaging within a cylindrical recess 40 in the next adjacent cutter member of the same cutter assembly.

The cylindrical bore 41 of each spigot 39 is coaxial with the shaft 14; but the cylindrical outer circumference 42 of each spigot has a centre 43 which is slightly offset radially from the axis 44 of the shaft. The recess 40 engaged by each spigot 39 has a diameter very slightly greater than that of the spigot, and its centre 45 is also radially offset by the same distance. Thus the spigots 39 and recesses 40 constitute eccentric elements intersected by the axis of rotation 44, and in each cutter member having a spigot 39 at one end and a recess 40 at the other, as shown in Figure 4, the offset axis or centre 43 of the spigot is itself angularly offset from the centre 45 of the recess at the other end of the same cutter member by an angle *B*, Figure 5. This angle *B* is shown exaggerated in Figure 5; a preferred value of the angle *B* is 5 degrees, though it may have any desired and convenient value.

The effect of this angular offset between successive eccentric centres 43 along a cutter assembly is that the centres of the spigots 39 in a cutter assembly such as those illustrated in the drawings, having three or more cutter members, define together a helix, or part of a helix, as indicated at 46 in Figure 4, concentric with the axis of rotation 44, so that each cutter element 24 is angularly displaced about the axis 44 with respect to the axis.

In assembling the cutter members on a shaft 14, one cutter member (50, Figure 4) is first secured to the shaft 14. The next cutter member 51 is then added so that the spigot 39 of the member 51 slides concentrically into the recess 40 at the rear end of the member 50. The cutter member 51 is then rotated slightly on the shaft 14 so that, by virtue of the slightly greater diameter of the recess 40 as compared with that of the spigot 39 the latter, at its point of greatest distance measured radially from the axis of rotation 44, engages the bore of the recess 40 in wedging relationship. This procedure is then repeated for the remaining cutter members 52 of the cutter assembly. The bore 53 of each cutter member is secured to the shaft 14, the spigots 39 to the recesses 40, and the end face 26 of each cutter member to the end face 27 of the next cutter member, by a suitable pre-applied industrial resin adhesive, for example a heat-curing thermoplastic adhesive. It will be realised from the foregoing that there is not only the angular offset *B* between the centre of a recess 40 and that of the next spigot 39 along, but also a slight angular offset between the centre of each recess 40 and that of the spigot 39 which it itself engages. Thus the centres 45 of the recesses 40 define a second helix 54, indicated in Figure 4.

Referring now once again to Figures 2 and 3, the machine includes, associated with the cutter assemblies 19 and 20, fixed re-circulation guide means in the form of plough-like guide members 55, for guiding material along a substantially controlled path from the discharge side of the co-operating cutter assemblies 21 and 22 towards the inlet side thereof. The term "discharge side" refers to the zone 56, Figure 3, at or immediately below the lower end of the cutting zone 23; the term "inlet side" refers to the zone 57 at or immediately above the upper end of the cutting zone 23.

Each guide member 55 is substantially arcuate in form, having a straight lead-in portion 58 and a straight exit portion 59, and is mounted on a web 60 which is carried by transverse beams 61, 63 in the case of the guide members associated with the cutter assembly 21, and beams 62, 64 in the case of those associated with the cutter assembly 22. The beams 61, 62, 63, 64 are part of the main frame 11, Figure 1, of the machine.

It will be seen from Figure 2 that each guide member 55 lies immediately below a respective one of the cutter members 21 or 22 and is concentric with the axis of rotation 44 of the associated cutter member. The exit portion 59 of each guide mem-

ber is arranged at a location well short of the inlet zone 57, and in this example it is disposed roughly diametrically opposite the latter. The guide members 55 are spaced radially outwards from the cutter members 21 or 22 by a distance C chosen to enable partially-comminuted material to be urged along the guide members by the projecting portions 36 of the cutter members, as will hereinafter be described.

Between each guide member 55 and the next, considered longitudinally with respect to the associated cutter assembly 19 or 20, there is a space 65 to allow material to fall therethrough to the bin 13, Figure 1. Thus the said guide means is seen to be discontinuous in the direction of the axes 44.

In operation of the machine described above with reference to the drawings, heterogeneous rubbish such as kitchen rubbish is put into the hopper 12. With the motor 18 rotating the cutter assemblies 19, 20 in the directions of the arrows 31, Figure 3, and at the same speed as each other, the material falls into the inlet zone 57 and is cut generally into strip-like form by the co-operating cutter elements 24 of the members 21 and 22 in the cutting zone 23. The strips of material as they are formed, together with any other particles of material cut or deformed to shapes other than strips, are forced downwards through the cutter assemblies to impinge on the guide members 55. It will be noted that the lead-in portion 58 of each guide member 55 is close to, or in actual contact with, the outer cylindrical surface of the bush 25 of a cutter member of the cutter assembly 19 or 20 which co-operates with the cutter assembly 20 or 19 respectively below which the guide member is fixed. Thus all the pieces of comminuted material are guided away from the cutting zone 23 by the guide members 55. Those pieces which are small enough will escape by falling directly through the gaps 65 and into the bin 13. Larger pieces, particularly those in the form of strips, are guided lengthwise along the guide members 55 and are urged therealong by the projecting teeth 36 of the cutter members. It will be realised that if such a piece of material is shorter than the pitch between two of the projecting portions 36 it will only be engaged by one of the latter and will tend to be pushed sideways so that it too falls through an adjacent gap 65.

If however a strip of material is long enough to be engaged on the appropriate guide member 55 by two or more of the projecting portions 36, it will tend to be urged thereby in controlled movement along the guide member as indicated by the arrows 66 in Figure 3 until it is pushed off the exit portion 59 moving then in a generally upward direction. It will be realised that the material is thence carried by the cutter members 21 or 22 upwards and over the top of the cutter assembly 19 or 20, but in a random or unconstrained manner as indicated by the arrows 67. What happens in practice is that some strip-like or elongate pieces of material, during this movement from the exit portions 59 of the guide members 55 to the inlet zone 57, tend to re-orientate themselves so as to lie across the cutter members, i.e. so as to extend in a direction generally parallel with the cutter shafts 14. A strip (whether so re-orientated or not), upon reaching the inlet zone 57, will typically be cut into several pieces, so that when these pieces reach the guide members 55 once again, all or some of them may be small enough to fall or be pushed through the gaps 65 between the guide members and so into the bin 13.

The arrangement whereby the lead-in portions 58 of the guide members 55 terminate close to the cutter member bushes 25, and are angled downwardly away from the bushes, ensures that strips of material shall not become entangled around the bushes. There may, however, sometimes—especially when dealing with heterogeneous material of widely differing shapes, sizes and textures, including for example such varied materials as metal, cardboard and plastics—be a tendency for cut or deformed pieces of material to become caught on the projecting teeth 36 of the cutter members 21, 22 or jammed between the cutter members and the guide members 55. Accordingly, the motor 18 may be arranged in known manner to undergo automatic reversal at predetermined intervals, so as to run the machine in reverse for a few revolutions. This tends to clear any jammed or fouling pieces of material. Alternatively, or in addition, the guide members 55 may be resiliently mounted, for example on coil springs, so as to tend to move away from the cutter members if subjected to the forces having generally radial components, which forces result if material is jammed between the guide member and the associated cutter member.

Referring now to Figures 6 and 7, the modified shredding machine shown therein is adapted for shredding large vehicle tyres, one being indicated at 70. This machine would, however, also be suitable for shredding other materials or objects, including heterogeneous rubbish and other materials for which the embodiment shown in Figures 1 to 5 would also be suitable.

The two cutter assemblies 71, 72 are arranged within the machine housing 73. Each assembly 71, 72 comprises cutter members 74, 75 respectively, each consisting of a disc-like cutter element having a pair of cutting edges defining end faces 76 which

inter-engage in generally the same manner as has already been described in detail in respect of Figures 1 to 5. The cutter members of each assembly are mounted alternately with spacers 77 on a hexagonal shaft 78 mounted in end bearings 79. Alternate members 74 of the assembly 71, and alternate members 75 of the assembly 72, are in the same angular position as each other with respect to the axis of rotation of the corresponding assembly. However, each member 74 or 75 is slightly displaced angularly from the next, as is best seen for the particular cutter members designated 74′ and 74″, and 75′ and 75″, in Figure 6. In addition, the cutter assembly 71 has one cutter member more than the assembly 72, so that each of the endmost members 74‴ of assembly 71 co-operates with only one of the members 75, but each of the other members 74 co-operates with two members 75.

The cutting edges of each cutter member or element 74, 75 define three radially projecting teeth 80, equally spaced and alternating with radial recesses 81.

One form of cutter element 75 is shown in Figure 8, dimensions again being in millimetres. Such an arrangement gives an included angle (corresponding to the angle A, Figure 3) of less than 40 degrees over substantially more than half the total periphery of each cutter member. With the dimensions indicated in Figure 8, the included angle is approximately 36 degrees over nearly 60 per cent of the periphery.

In addition to the end bearings 79, there is provided an intermediate support means 82, 83 for each of the cutter assemblies 71, 72 respectively. These support means are constructed and arranged generally similarly to each other and the support means 83 only will therefore be described. It is arranged between two adjacent cutter elements 75 and comprises a pair of support members in the form of the outer rings of roller bearings 84, 85 mounted on stub shafts 86 which are fixed in a robust bearing housing 87 secured by bolts 88 to the machine housing wall 89. Each roller bearing outer ring is freely rotatable about the axis of its stub shaft 86, these axes being parallel with the axis of the cutter shaft 78 but not in a common plane therewith. The outer rings are normally just out of contact with the spacer 77.

Also provided are inlet guide means which comprise four top ploughs or guide assemblies 90, and two further top guides 91. Each guide 91 is part of the appropriate bearing housing 87 and comprises a fixed guide plate 92 directed generally towards the cutting zone 93, and a top plate 94. Each top plough 90 comprises a fixed guide plate 95 and a support plate 96, both fixed to a longitudinal bar 97 extending between brackets 98 which are fixed to an angle deflector plate 99 secured to the corresponding machine housing wall 89. The guide plates 95 and support plates 96 are disposed between adjacent cutter members and straddle, and are supported by, the appropriate spacer 77. The guide plates 92, 95 are arranged at approximately the same angle to the vertical, and those associated with the cutter assembly 71 are convergent with those associated with the assembly 72, as can be seen from Figure 6.

In operation, when a tyre 70 is urged downwards by a suitable ram or pusher (not shown) its lowest section is forced between shown) its lowest section is forced between the guide 91 and between the top ploughs 90, the guide plates 95 distorting the rubber downwards and outwards longitudinally until it becomes caught by the cutters which cut the rubber into strips. Recirculation and further cutting takes place as already described with reference to Figures 1 to 5. At the centre of each cutter assembly, the latter is protected from undue deflection by the support means 82 and 83.

The cutter elements may have any convenient number of projecting teeth, most typically three, four, five or six.

WHAT WE CLAIM IS:—

1. A shredding machine of the kind hereinbefore specified, wherein each cutter element lying between two cutter elements of a co-operating cutter assembly has two said cutting edges, each of which is substantially continuous and bounds substantially all of a respective one of the two opposed end faces of the element in face-to-face engagement with the co-operating cutter element, so that the number of said perpendicular interfaces is one less than the total number of cutter elements in two co-operating cutter assemblies.

2. A machine according to Claim 1, wherein there are two cutter assemblies one of which has one cutter element more than the first cutter assembly.

3. A machine according to Claim 1 or Claim 2, wherein each cutter element is angularly displaced about the axis, with respect to the next in the same cutter assembly.

4. A machine according to Claim 3, wherein alternate cutter elements of a cutter assembly are in the same angular position as each other with respect to the axis, each cutter element being angularly displaced from the next.

5. A machine according to any one of the preceding claims, wherein the shape of each at least one pair of co-operating cutting edges is such that, over at least a major portion of each revolution, the included angle (as hereinbefore defined) between

them is such as to cause a positive cutting action to occur between the corresponding cutter elements.

6. A machine according to Claim 5, wherein the said shape is such that the said included angle has a value of 40 degrees or less over substantially more than half the total periphery of each corresponding cutter element.

7. A machine according to Claim 6, wherein the said shape is such that the said included angle has a value of 30 degrees or less over at least 90% of the periphery of each corresponding cutter element.

8. A machine according to any one of the preceding claims, including fixed recirculation guide means associated with the cutter assemblies, for guiding material along a substantially controlled path from the discharge side of the co-operating cutter assemblies towards the inlet side thereof, the guide means being discontinuous in the direction of the cutter assembly axes so that material of sufficiently small size can escape.

9. A machine according to Claim 8, wherein said guide means include a fixed substantially arcuate plough-like guide radially spaced from each cutter element and extending partway around the cutter element.

10. A machine according to any one of the preceding claims, including inlet guide means having a fixed guide member between one cutter element and the next in the same cutter assembly, the or each said guide member being directed generally towards a cutting zone in which co-operating end faces of the cutter elements overlap.

11. A machine according to Claim 10, wherein the said guide member or members associated with one of the cutter assemblies is/are convergent with that or those associated with another of the cutter assemblies which co-operates with that assembly.

12. A machine according to Claim 10, wherein the inlet guide means includes between one cutter element and the next a support member fixed with respect to the associated fixed guide member and arranged so that the support member and guide member straddle and are supported by a spacer element between the opposed end faces of the said one and the next cutter element.

13. A machine according to any one of the preceding claims, wherein each cutter assembly is mounted for rotation in end bearings, and including intermediate support means for at least one of the cutter assemblies the or each intermediate support means being between two adjacent cutter elements and comprising a pair of support members freely rotatable about axes disposed parallel to the corresponding cutter assembly axis but not in a common plane therewith.

14. A shredding machine of the kind hereinbefore specified, constructed, arranged and adapted to operate substantially as hereinbefore described with reference to, and as illustrated in, Figures 1 to 5 of the accompanying drawings.

15. A shredding machine of the kind hereinbefore specified, constructed, arranged and adapted to operate substantially as hereinbefore described with reference to, and as illustrated in, Figures 6 to 8 of the accompanying drawings.

SAUNDERS & DOLLEYMORE
Chartered Patent Agents
2a Main Avenue, Moor Park,
Northwood, Middx. HA6 2HJ.
For the Applicants.

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1454288 COMPLETE SPECIFICATION

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Sheet 1

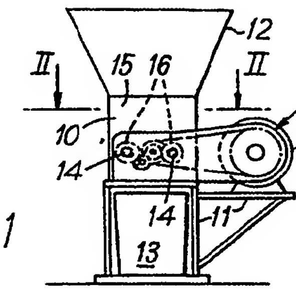

FIG.1

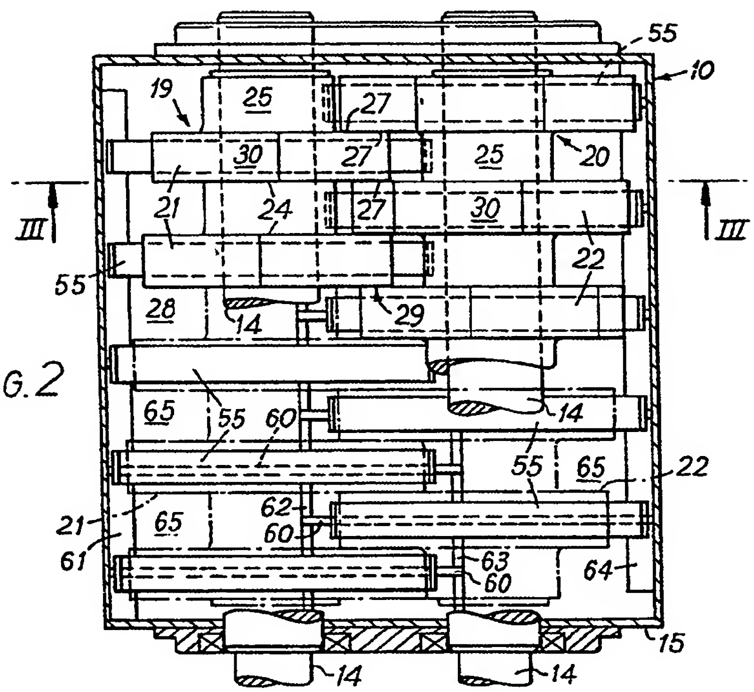

FIG.2

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Sheet 2

FIG. 3

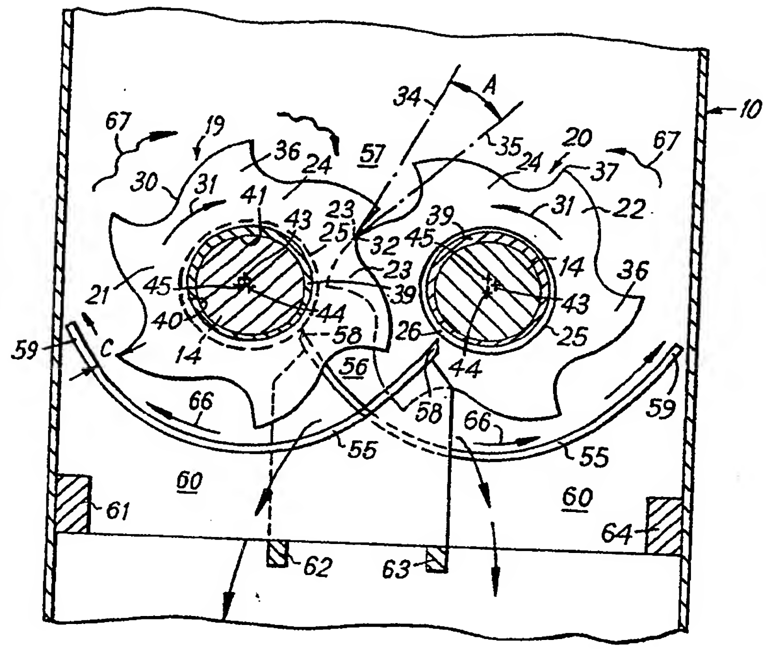


FIG. 4

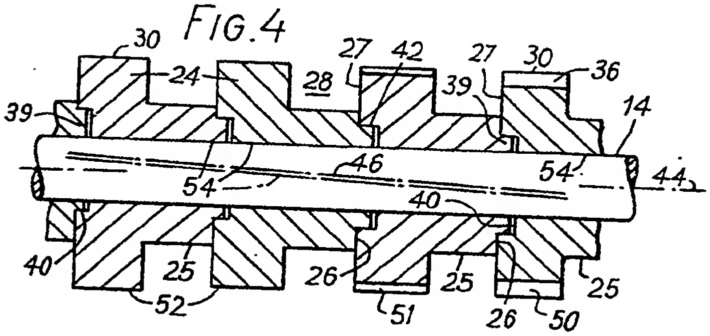
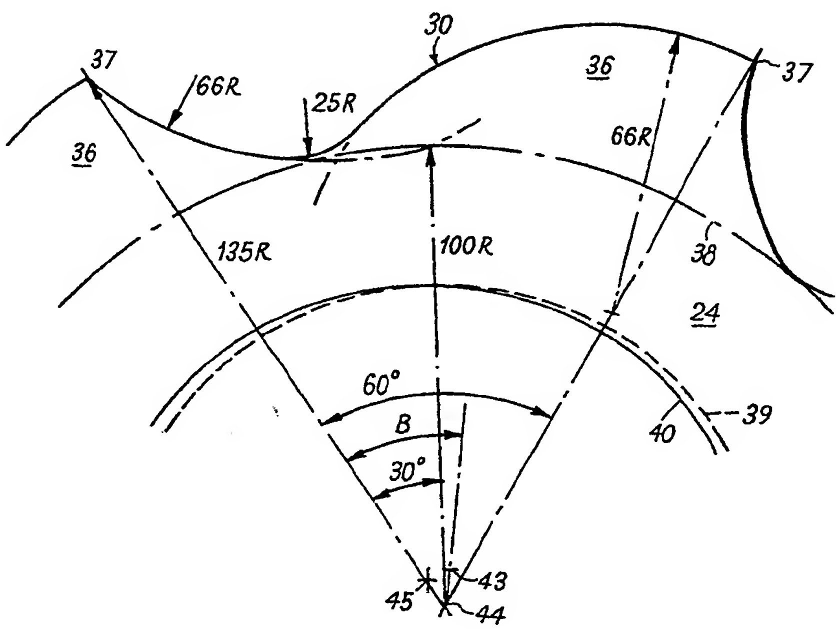


FIG.5



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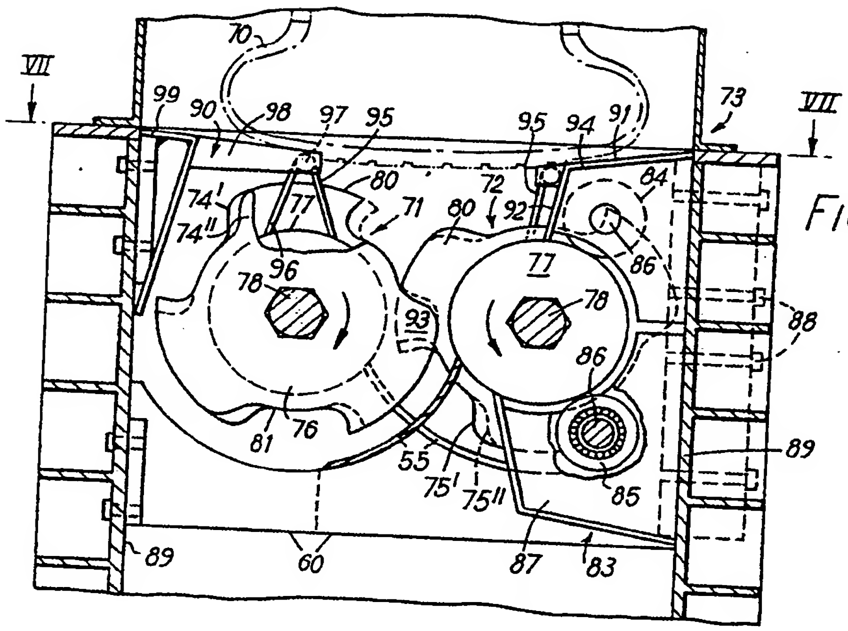

FIG.6

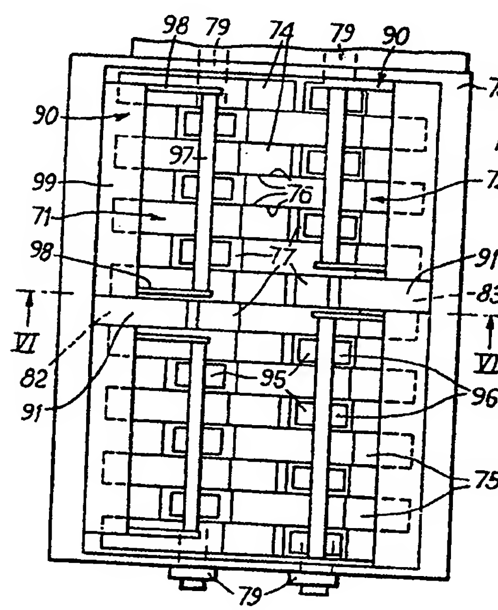

FIG.7

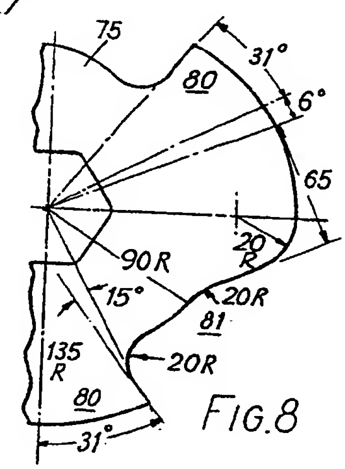

FIG.8